

January 2020

“Child Health, Plagues, Agricultural Shocks,
Differences-in-Differences.”

Bruno Conte, Lavinia Piemontese and
Augustin Tapsoba

Ancient Plagues in Modern Times:

The Impact of Desert Locust Invasions on Child Health*

Bruno Conte[†] Lavinia Piemontese[‡] Augustin Tapsoba^{†§}

December 2, 2019

Abstract

This paper estimates the causal impact on child health of a locust plague that occurred in Mali during the mid 2000s. Using a Difference-in-Differences strategy, we show that children who were exposed in utero to the plague suffer major health setbacks. Affected children have, on average, a height-for-age Z-score 0.33 points lower than non-exposed children. We argue that, in this type of agricultural economy, locust invasions could have an impact on child health mainly through two channels: first, a speculative/anticipatory price effect that kicks in during the plague itself, followed by local crop failures effect that would constitute an income shock for affected farmers and a local food supply shock for markets. We find that children exposed only to the speculative price effect in utero suffer as much as those exposed to the actual crop failure effect.

Keywords: Child Health, Plagues, Agricultural Shocks, Differences-in-Differences.

JEL Codes: I15, O12, Q12, Q18.

*We are very thankful to Joan Llull and Hannes Mueller for their support and invaluable guidance. We acknowledge the very useful comments from Oriana Bandiera, Andre Groeger, Ada Ferrer-i-Carbonell, Ana Rute Cardoso and Pau Milán. We also would like to thank the participants of the ENTER exchange seminar in Mannheim, the Einaudi Foundation in Turin, the Barcelona GSE Jamboree, the UAB Applied seminars series, and the UPF Political Economy reading group. All errors are ours.

[†]bruno.conte@barcelonagse.eu Universitat Autònoma de Barcelona and Barcelona GSE

[‡]lavinia.piemontese@ens-lyon.fr University of Lyon, ENS Lyon, GATE Lyon/St-Etienne

[§]augustin.tapsoba@tse-fr.eu Toulouse School of Economics

1 Introduction

Climate change is receiving considerable attention both from the media and the academic community. One of its consequences is an increase in the likelihood and intensity of extreme weather conditions, which in turn can lead to severe agricultural shocks. These shocks can affect the households that are relying on local agricultural production, with serious repercussions for young children. This is due to the fact that conditions experienced early in life have long-lasting effects on various socioeconomic outcomes. In particular, it is well established that harsh conditions experienced in utero can have detrimental and persistent effects on individual health throughout the whole life cycle (Stein et al., 1975). This concept, known as the fetal origins hypothesis, implies that it is harder to remedy bad fetal health later on in life.¹

In this paper we study the impact, on child health, of exposure to a specific type of agricultural shock that is indirectly linked to extreme weather conditions and climate change: the damage caused by desert locust plagues.² Locust swarm invasions are destructive events that recurrently put at risk food supply in many developing countries (Brader et al., 2006). They are caused by a specific species of grasshoppers that usually live, in their solitary phase, around the Sahara desert. Under favorable breeding conditions (excess rainfall), these grasshoppers go through a gregarization process with substantial changes in their behavior, morphology and physiology. They become more voracious and can grow into huge swarms that travel to less arid areas to feed

¹On the one hand Almond and Currie (2011) provide an excellent review on the fetal hypothesis theory and its theoretical relation to later life outcomes. On the other hand, the empirical literature has successfully documented the impact of adverse in utero conditions on infant mortality (Kudamatsu et al., 2012; Dagnelie et al., 2018), child health (Akresh et al., 2011, 2012a; Bundervoet et al., 2009), adult health (Akresh et al., 2012b; Maccini and Yang, 2009), and adult socioeconomic outcomes such as literacy, educational attainment, income and labour market status among others (Almond et al., 2007; Alderman et al., 2006; Lavy et al., 2016).

²The direct consequence of extreme weather conditions and climate change on agricultural production is through crop failure due to droughts or floods.

and reproduce causing devastating effects on agricultural production.³

We study whether early-life exposure to the most recent plague that occurred in Mali, between July and October 2004, led to detrimental effects on child health. While the impact of food shortage on child health has been explored extensively in the literature, uncovering the channels through which agricultural shocks impact health is still a standing question. We make a step in this direction, arguing that this type of pest invasion can affect households living in areas with a single harvest per year through two main channels. First, there is a *speculative price effect* that could kick in immediately during the growing season in which the plague is occurring in anticipation of the upcoming harvest failure. At this point, households and markets are still relying on the harvest from the previous agricultural season. However, crop destruction by the pest in the ongoing season could lead to an anticipation of a future crop supply shock and drive up prices in local markets. Second, there is the actual *crop failure effect* that would constitute an income shock for farmers and a supply shock for markets after the harvest of affected crops. This effect should last at least until the following harvest.⁴

We are able to explore these mechanisms by making use of a minutely identified agricultural shock. Specifically, we rely on the exact timing and the precise location of locust swarm events to identify the temporal and spatial variation in the exposure of different birth cohorts to the 2004 locust plague in Mali. We use geocoded household survey data with detailed information on birth history and health outcomes of children from the Demographic and Health Surveys (DHS). Data on the timing and location of locust swarm invasions comes from the locust monitoring system run by FAO Desert Locust Information Service (DLIS).

³Beyond the direct effect of extreme weather conditions on agricultural production, here we consider how such unusual weather conditions could affect agricultural production in an entire region. We focus in particular on the consequences of desert locust plagues that occur as a consequence of such extreme weather conditions in arid areas around the Sahara desert.

⁴Locust plagues can also have a persistent effect if, for instance, the failed harvest in a given agricultural season affects the quality of seeds used for the next one. We found no evidence of such long-term effect.

Using a Difference-in-Differences identification strategy, we show that children exposed in utero to the adverse effects of the locust plague suffer major health setbacks. Exposed children have, on average, a height-for-age Z-score 0.33 points lower than non-exposed children. We find no impact for cohorts of children exposed to the shock after birth. We also study the timing of the estimated effect and we show that cohorts of children that were subject only to the *speculative price effect* in utero suffer as much as those exposed to the actual *crop failure effect*. Our results are robust to specifications that include region-specific time trends, household and mother characteristics, climate shocks, and mother fixed effects. They are also not affected by issues of endogenous migration.

This paper belongs to two main strands of the economic literature. First, it contributes to the literature on the importance of early life conditions (Lavy et al., 2016; Maluccio et al., 2009; Black et al., 2007; Behrman and Rosenzweig, 2004; Stein et al., 1975). A substantial part of it focused on identifying the effect on child health of exposure to weather shocks (Maccini and Yang, 2009), civil wars (Dagnelie et al., 2018; Valente, 2015) or adverse institutional setup (Kudamatsu, 2012). We complement this literature by investigating the impact of desert locust plagues on child health. One of the novelties of our analysis relies on the use of a shock characterized by a clear-cut spatial and temporal variation, i.e. geolocated locust swarm invasions. Moreover, this is the first paper, to the best of our knowledge, to shed lights on the channels through which such pest invasion can affect households. In particular, we provide evidence of a clear distinction between the purely speculative price effect and the actual crop failure effect of the exposure to the swarm invasions. We also show that this shock has long-lasting health effects on children exposed in utero, but no effects after birth. Through several alternative specifications of our model, we show that the adverse effects are present for both male and female children. This contrasts with recent evidence in the literature on early life development, which generally finds larger adverse effects on females (Lavy et al., 2016; Akbulut-Yuksel, 2017; Dagnelie et al., 2018).

Second, this paper clearly adds to the literature that studies the consequences of negative agricultural shocks caused by pest invasions. [Baker et al. \(2018\)](#) show that the boll weevil’s pest invasion that affected US cotton production from 1892 to 1922 led to an increase in educational attainment due to reduced opportunity cost for schooling. [Banerjee et al. \(2010\)](#) show that phylloxera invasion in 19th century France affected wine production and led to substantial effects on adult height for people born in affected areas in that period. [De Vreyer et al. \(2014\)](#) used locust plague invasion in 1987-1989 in Mali to show that it had a long term effect on educational attainment. Our paper is closer to the latter, since we study the consequences of invasions of the same pest species but on a different outcome, and, as argued above, we provide the first evidence on the mechanisms through which pest invasion can affect households.

The remainder of this paper is organized as follows. Section 2 provides some background on the 2003-05 locust plague in Western Africa and its relation to food shortages and child health in Mali. Section 3 presents the data used for the empirical analysis. Section 4 discusses the channels through which locust invasions can affect the well-being of households. Section 5 presents the empirical strategy used and Section 6 shows the results obtained. Section 7 concludes.

2 Background

In this section we describe the context of our analysis. We first provide a general description about the desert locusts, their habitat and their relation with climatic conditions that can turn them into an agricultural plague. We then provide some details of the locust plague that took place in the Sahel region in the mid 2000s, stressing on its consequences in Mali.

2.1 Desert Locust Plagues

Desert locusts are insects that live in the arid and hyper-arid zones of the Sahel region, northern Africa, Middle East and southeast Asia, as shown in Figure 1. They pertain to the family of

grasshoppers and normally inhabit desert zones, called *recession areas* (bounded by the black solid line in Figure 1), in a solitary, harmless and integrated way with the local ecology. What makes them different from traditional grasshoppers is their capacity to mutate physically and change behavior under certain conditions. In particular, if specific areas called *breeding areas* (green and ocher areas in Figure 1) experience periods of excessive rainfall, followed by periods of relatively mild temperatures, a process of fast reproduction takes place. The high density of locusts combined with a relative shortage of vegetation induce them to a *gregarious stage*: the locusts mutate physically and start behaving as a unique group, known as a *swarm*.

Upon gregarisation, these groups become more and more voracious and reproduce faster. If needed, locust swarms will fly away to find a location with vegetation for feeding and appropriate conditions for reproducing. Within a few weeks after settling in a suitable new location, there can be a new generation of gregarious locusts. The increase in the size of the swarm can be remarkable: the incorporation of locusts from the new generation can lead up to a ten-fold increase in the size of the swarm (FAO, 2004). If breeding conditions are favorable and in absence of human intervention, the density of a swarm can become extremely high, having over a billion insects.

Desert locusts swarms are very threatening because, while flying in search of new locations for feeding and reproducing, they end up following winds that move them away from the most desert areas of the Sahara. Usually, the winds blow them towards the central Sahelian and tropical areas in the South or the Mediterranean regions in the North. These *invasion areas*, shown in Figure 1 by the dashed red line, span over more than 50 countries and have a total surface of about 29 million square km (Herok et al., 1995). These zones are more densely populated and are used for agricultural production. Thus, crop yields and/or pasture vegetation can be partially or totally consumed by the swarms, potentially threatening the food supply of entire regions⁵.

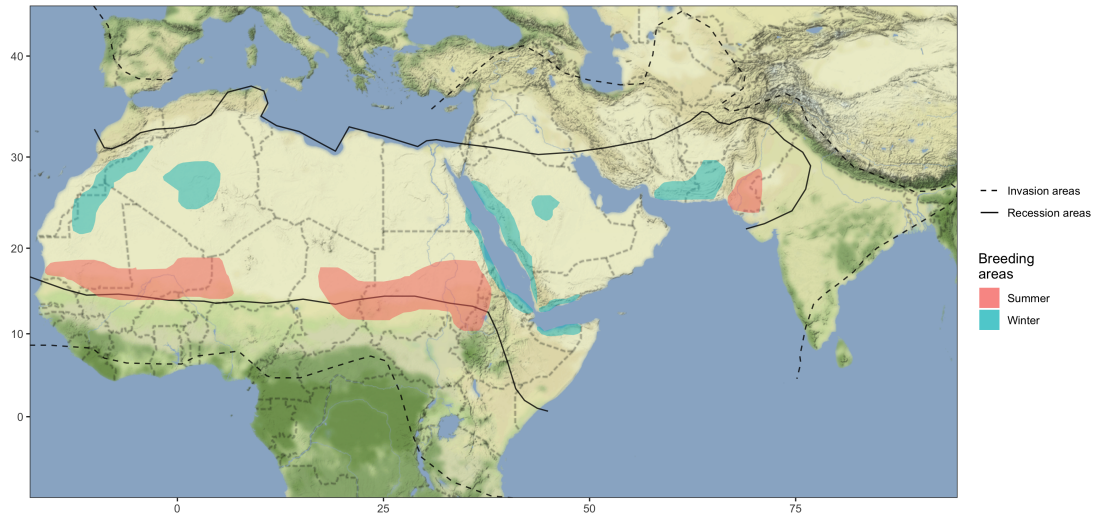
⁵A locust swarm can cover from one to several hundred square km, and each square km of the swarm

Moreover, the fact that the swarms can fly for very long distances, over hundreds of kilometers in a single day, implies that favorable conditions for gregarisation in one place can create severe repercussions in relatively far away locations.

If climate conditions remain favorable for a long time within large geographic areas, the swarming, breeding and migration behaviour of locusts can create a regional plague, i.e. when locust swarms multiply exponentially in size and number and spread over several countries. If so, food security in multiple countries can be under risk. Moreover, fighting the plague in these circumstances is extremely difficult and costly. Fortunately, such events are not very recurrent nowadays – as seen in Figure 2, there has been relatively little plague peaks from 1970 vis-a-vis the preceding period. This reduction is associated to active human preventive intervention ([Cressman and Stefanski, 2016](#)). The ones that managed to take place since the 1970, however, happened to be extremely severe. This is the case of the plague occurred between 2003 and 2005, whose consequence we analyse in this paper.

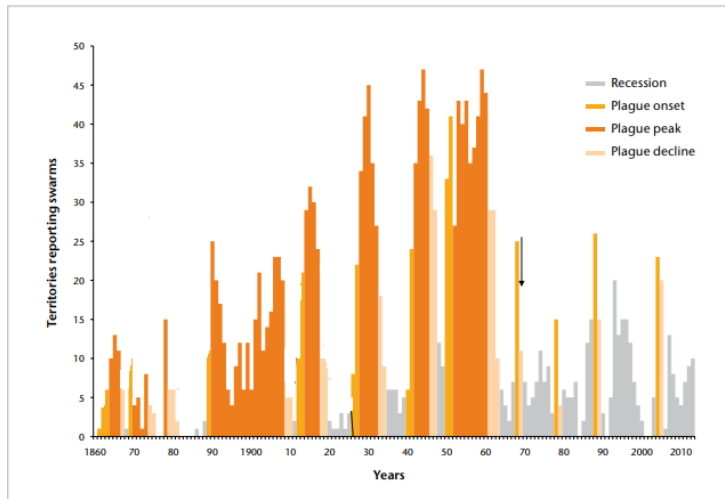
has at least 40 million locusts. A one square km swarm can consume daily the equivalent food consumption of 35,000 people ([Symmons et al., 2001](#))

Figure 1: Affected Areas



Note: Authors' calculation based on [Cressman and Stefanski \(2016\)](#)

Figure 2: Historical plagues



Source: [Cressman and Stefanski \(2016\)](#)

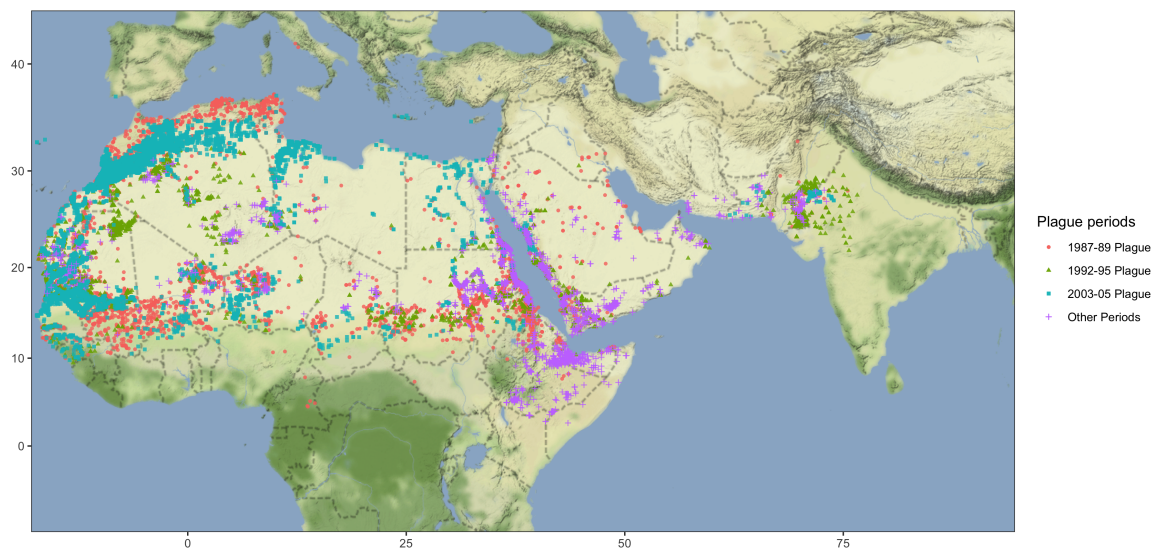
2.2 The 2003-2005 Desert Locust Plague

The 2003-2005 desert locust plague started from optimal climate conditions occurred in late 2003 and escalated to a massive plague throughout the entire Western Africa in 2004 ([Ceccato et al.](#),

2007), peaking in the third quarter of that year. Importantly, it developed from independent outbreaks that took place in different locations, taking the international prevention community by surprise (Cressman and Stefanski, 2016). Figure 3 illustrates the extension of the plague in terms of number of swarm events and geographical coverage. It affected multiple countries, mostly in West Africa and North Africa, but also in central and eastern territories.

The 2003-2005 locust plague created a regional food crisis that involved more than eight million people in the whole Sahel region, implying a huge cost. On top of its direct cost (that includes the agricultural lands and the crops damaged), of which there is not a precise estimate, there was a substantial collateral cost of more than 400 million dollars needed to control the invasion (Brader et al., 2006). This loss does not include the indirect cost that the plague entailed, such as forgone investment for other national development activities or significant increase of food prices (Brader et al. (2006) and FAO (2005a)).

Figure 3: Geographical Distribution of Locust Swarms from 1985 to 2016.



Source: SWARMS data base from FAO Desert Locust Information Service. See Section 3.

2.3 The case of Mali

Mali is a landlocked country in West Africa with a surface of about 1.2 million square km, spread in latitude across three different climate zones: the desert zone (Saharan), the transition zone (Sahel) and the tropical zone. As Figure 1 depicts, a substantial part of its territory is a locust breeding area, which makes it very likely to experience (or be invaded by) locust swarm outbreaks.

This country constitutes a relevant case study for our analysis for several reasons: first, as mentioned above, Mali is located in a very risky area in terms of likelihood of experiencing locust plague invasions. Second, the pattern of the 2003-2005 swarm invasions was unevenly spread over its territory, allowing us to exploit this spatial variation together with variation in the timing of the plague in our empirical exercise. Third, this country was, by then, a very poor agricultural economy.

Table 1 provides an overview of the country (we use data published by the World Bank). Mali is classified as a low-income country, with a GDP per capita ranked 160th, with more than the 40% of its population below the poverty line. Malian population, of approximately 19 million individuals, is largely present in rural areas (about 60% and almost 69% in 2004, the most intense year of the locust plague). Mali is strongly dependent on agriculture, which accounts for about 40% of its GDP (in the 2004 this share was 30%) and is still largely composed by small-scale subsistence farming. As such, a large share of its population is vulnerable to agricultural hazards such as droughts and plagues.

Table 1: Overview of Mali

	Most recent value	2004 value
Population (million)	19.08	12.37
Rural population (% of total population)	57.64	68.70
GDP per capita, PPP (constant 2011 USD)	2,056.00	1,710.11
Poverty headcount ratio at national poverty lines (% of population)	41.1	41.7
Life expectancy at birth (years)	67.48	51.22
Agriculture, forestry, and fishing, value added (% of GDP)	38.53	30.02

Data source: The World Bank country data. The most recent value for variables “Population”, “Rural Population”, “GDP per capita”, “Life expectancy”, “Agriculture, forestry, and fishing, value added” is year 2018. Since there is no available time series for variable “Poverty headcount ratio at national poverty lines”, its most recent value is year 2009, while its 2004 value corresponds to year 2006.

Not surprisingly, Mali was among the countries that have been mostly damaged by the locust plague of 2003-2005. According to [Brader et al. \(2006\)](#), 1 million people were affected by the locust swarm invasion object of this study. Exact estimates of the agricultural losses are not available, but the existing evidence suggests that the plague had devastating effects. [Brader et al. \(2006\)](#) states that in Mali, the losses caused by the 2003-2005 plague have been evaluated at 90% of the expected cereal production in the zones investigated, moreover one-third of the pastures were lost in the same areas. By mid-2005, [FAO \(2005b\)](#) reported alarming increases in cereal prices and a deterioration of conditions for livestock production in both countries. Moreover, the poorest households suffered the most from this situation as the report states that by the mid 2005, *"access to main food staples [was] increasingly difficult for vulnerable households and pastoralists. Severe child malnutrition [was] increasing rapidly."* ([FAO, 2005b](#)).

3 Data and Descriptive Statistics

In order to study how child health was affected by exposure to locust plagues in Mali, we collected data from three different sources: (i) information on locust swarms are obtained from a rich database of worldwide locust monitoring, (ii) data on children anthropometrics is gathered from DHS, a widely used household survey, and (iii) we complement these two data sources with climate data and other geographical characteristics at the spatial cell level from PRIO-GRID dataset.

3.1 Locust Swarm Data

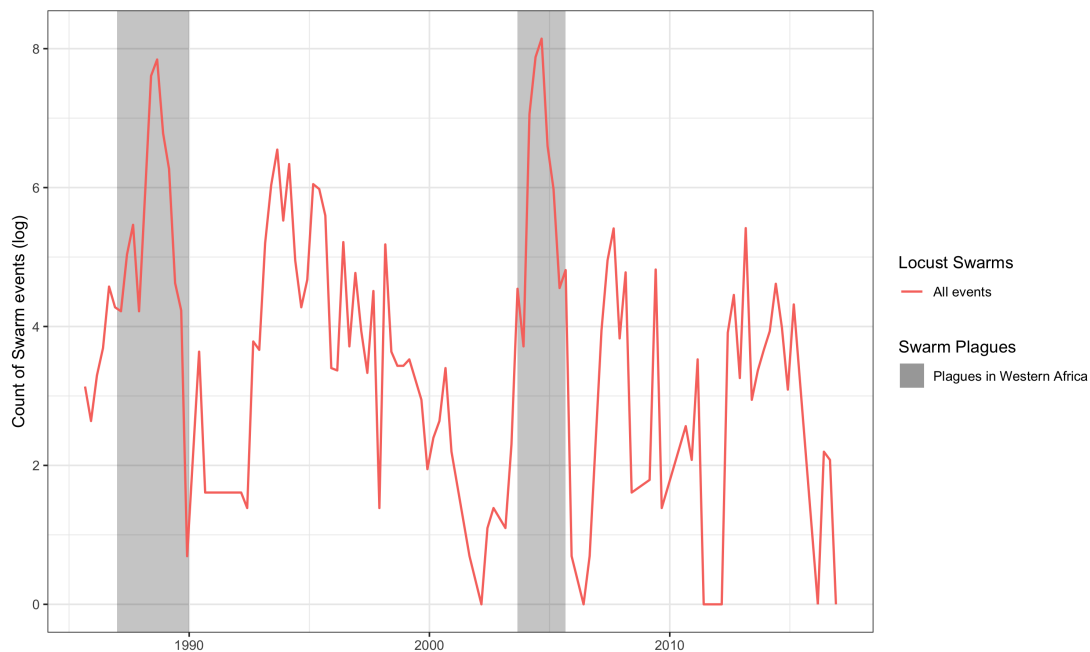
We collect geographical and temporal incidence of locust swarms from the SWARMS database ([Cressman, 1997](#)). SWARMS contains historical geocoded information on many “locust parameters” including local breeding conditions, the incidence of adult locusts, hopper bands, swarms, and many others. For this application, we select information exclusively on locust swarms. Therefore, for each event related to the presence of a locust swarm, we collect the date and the geographic coordinates in which the event occurred.

The SWARMS system is held and maintained by the FAO Desert Locust Information Service (DLIS) Unit. This unit is monitoring, preventing and controlling locust incidence in the Sub Saharan Africa for over 60 years. For this, a national office at each of the countries in the region conducts field activities. These activities include field incursions into areas prone to locust incidence and reproduction to search for (and code if found) locust bands and swarms. The coding is done in-field with a satellite-based technology; the information is automatically sent to the FAO-DLIS headquarters to be further cleaned if necessary. The data is complemented with information from local villages which self-report to field officers and/or the national DLIS office.

The resulting data on the incidence of locust swarms spans from 1985 to 2016 and covers 43 countries. Figure 4 shows the distribution of locust swarm incidence over time. It is quite

consistent with the historical evidence of locust plagues (Figure 2), i.e. there are two main peaks of events involving swarms in late 1980s and mid 2000s. Analogously, the geographical distribution of the swarms is also consistent. As seen in Figure 3, most of the events from the 1987-89 and 2003-05 plagues are concentrated in the Western/North-Western Africa, as expected. The same holds for the events from the 1992-1995 upsurges in the Horn of Africa and South Asia, and the most recent plagues in the Horn of Africa. As the interest of this study is the plague of 2003-2005, we filter from this dataset only events from these years. In Mali, approximately the 90% the total number of the locust swarms related events took place in 2004, therefore in our analysis we use events from 2004 only.

Figure 4: Quarterly Sum of Locust Swarms (in logs) for all regions from 1985 to 2016.



Source: SWARMS data base from FAO Desert Locust Information Service. See Section 3.

The consistency of the SWARMS data in the temporal and spatial dimensions does not rule out the possibility of measurement error. The first challenge concerns the potential issues that the DLIS National Offices could face to keep field operations consistently and evenly over time

and across different countries. Secondly, the political instability and/or the incidence of civil conflicts in many Sub Saharan Africa countries could weaken the operational capacity of field teams. These sort of complications could lead to miscoding and lack of data in specific areas and/or time periods. We rule out these possibilities in our study for two main reasons. First of all, we verified that for our case study during the time period of our analysis (Mali in mid 2000s) the National Desert Locust Offices have not faced drastic changes and other difficulties that could affect its field operations.⁶ Regarding the potential issues linked to political instability, during the time period of interest, there have not been political crisis and/or civil wars in the region of study.

3.2 Children Anthropometrics Data

Information on child health in Mali is obtained from the Demographic and Health (DHS) Surveys. DHS surveys are being conducted in many developing countries since late 1990s with a standardized and nationally representative data collection methodology. The interviews target female individuals, aged from 15 to 49 years old. For a subsample of respondents' children aged up to 5 years old, anthropometrics as height and weight are collected by trained surveyors. Importantly, children height are provided in Z-scores, i.e. the difference between the child's height and the mean height of the same-aged international reference population, adjusted by the standard deviation of the reference population.

Moreover, DHS surveys provide GPS coordinates of the household location, called cluster.⁷ These coordinates are released with a random noise for privacy reasons (set to up to 2 km for clusters located in urban areas, 5 km for those in rural areas, and 10 km for 1% of the latter).

⁶This information was provided unofficially by an Information Officer at the DLIS office at FAO, Rome.

⁷Empirical work using DHS data also call the clusters as enumeration areas or locations. We use the terminology of DHS cluster or enumeration area without distinction.

The locations of the clusters are drawn independently – thus differ – in each DHS wave. In order to have a geographical unit that is comparable across waves, we also collect the coordinates of the 0.5° grid cell that each cluster lays over.

In this analysis we use wave V and wave VI of DHS survey, whose interviews took place in 2006 and 2012/13 respectively. Therefore, children who were measured during the interviews belong to birth cohorts from 2001 to 2013, covering the period of the plague. In particular, children measured in the first wave are those whose cohort of birth can potentially coincide with the plague period. Children from the second wave, instead, are too young to have been exposed. To enrich the set of variables available, the data of each child was linked to its household and mother’s characteristics.

To have a broad picture of the socioeconomic conditions of our population of interest, Table 2 provides some descriptive statistics of the household and mothers characteristics. We distinguish between households located in areas exposed to the locust plague and the remaining ones⁸. Table 2 suggests that there are not remarkable differences between treated households and the remaining ones. On average, surveyed households are headed by people in their early 40s and the gender distribution of head of household is even. More than the 70% of the surveyed households are located in rural areas. Concerning the distribution of wealth, compared to the control group, the treatment group has 5% less poor household and 5% more rich household. On average, mothers are slightly more than 160 cm tall, have a very low education level, i.e. only one year, and have more than two children aged 5 years or younger.

⁸An area is defined as exposed if it is located within 30 km from at least one locust swarm event during the plague.

Table 2: Descriptive statistics

		Treatment	Control	Difference	Standard Error
Age of head of household (years)		41.66	41.70	-0.04	0.28
Head of household is female (percentage)		49.59	49.21	0.39	1.18
	Poor	35.82	41.53	-5.33***	1.16
Wealth of household (percentege by cathegory)	Middle	21.28	20.89	0.39	0.96
	Rich	42.90	37.95	4.95***	1.15
Rural residence (prcentage)		71.98	72.30	-0.32	1.06
Height (in centimeters)		162.70	161.12	1.11***	0.17
Education (years)		0.95	1.00	-0.05	0.06
Number of children 5 years old and under		2.30	2.29	0.02	0.01
Number of observations		12,118	2,091		

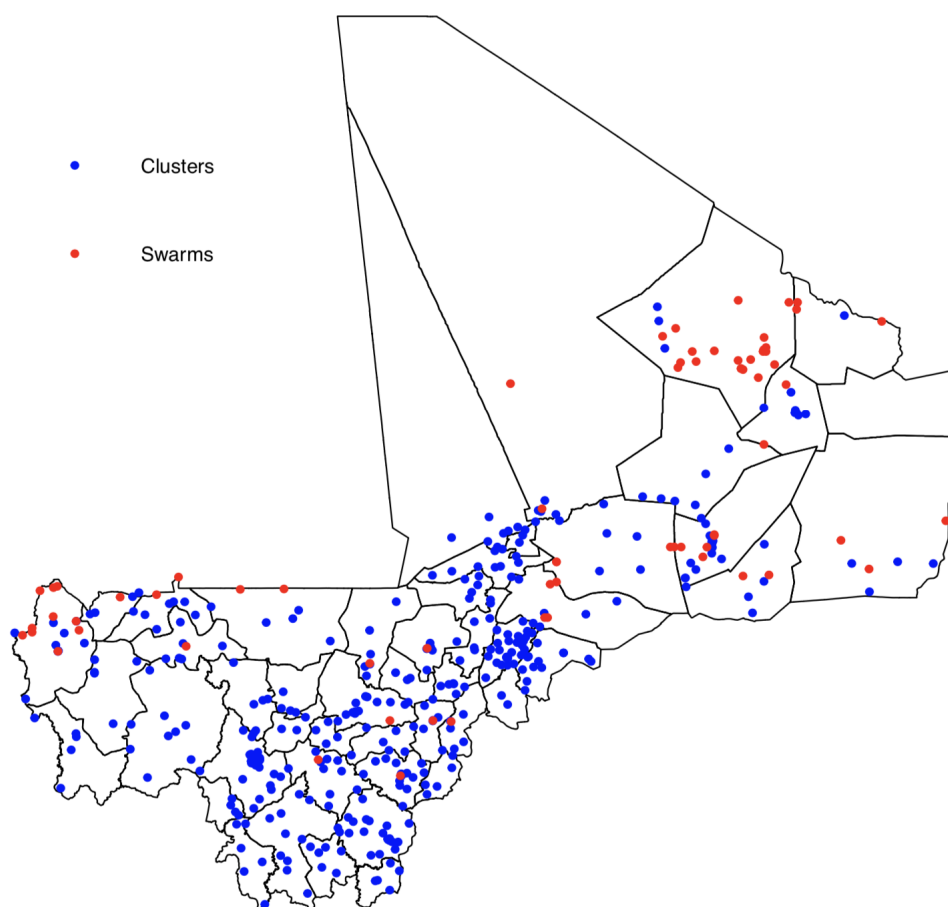
Source: DHS data, Mali waves 2006 and 2012. The table reports average values of each variable, computed for the treatment and the control groups. The former group consists of households located within a 30 kilometers from a locust swarm event. The third column reports the difference between the averages of treatment and control group for each variable. The fourth column reports the standard error of the difference. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 5 depicts the spatial distribution of household clusters and locust swarms events in Mali. We can notice that the potentially treated clusters are mainly located in the eastern part of the country, where the most of the swarm events occurred. The remaining potentially treated clusters are located in the western and central regions of the country. This makes sense as these territories coincide with the breeding area depicted in Figure 1 and the northern part of the country is constituted by the Sahara desert.

3.3 Spatial Cell Data

The georeferenced feature of the household and locust swarms datasets allows us to aggregate more information for our analysis. We add to the data described above geographical information from the PRIO-GRID dataset (Tollefsen et al., 2012). This is a geocoded dataset, whose statistical unit is spatial cells of 0.5×0.5 degrees. Moreover, we collect weather data from the Standardized

Figure 5: Locust invasion and household clusters in Mali



Source: SWARMS data base from FAO Desert Locust Information Service and DHS data, Mali waves 2006 and 2012.

Precipitation-Evapotranspiration Index (SPEI), a multiscalar drought index which considers the joint effects of precipitation, potential evaporation and temperature ([Vicente-Serrano et al., 2010](#)). This allows us to take into account the fact that the impact of rainfall on the growing cycle of a plant depends on the extent to which water can be retained by the soil.⁹ This dataset is available at the 0.5×0.5 degrees, and so matched to the household coordinates.

4 Effect of Locust Invasions on Child Health: Three Potential Channels

In this paper, we are interested in understanding how early life exposure to the 2004 desert locust plague could have affected child health using data from Mali. The mechanism that links the two elements is economic – as mentioned above, the plague of interest created a severe food crisis in Mali. We expect that to translate into a shock to the caloric intake at the household level, which in turn would hinder the development of young children.

The relation between the timing of the exposure to the plague and food shortage is, however, not straight forward. The agricultural production has a cyclical nature, following a region specific seasonal calendar. Crop damages caused by locust swarms in a period of time might not affect the food supply at that moment if markets are still relying on previous season’s production. Therefore, to understand how the 2004 plague could have affected households in Mali, we first need to understand on which harvest households and markets were relying in each period.

Figure 6 shows the seasonal agricultural calendar in Mali ([FEWS-NET, 2005](#)). It starts with soil preparation between March and May followed by planting in May-June. The growing season

⁹See Appendix A3 for a description of how we construct index of local weather shocks using SPEI index.

Figure 6: Seasonal Calendar

Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Dry Season Soil Preparation		Planting		Growing Period			Harvest		Dry Season		

Source: FEWS-NET (2005)

happens between July and September and harvest period is in October/November. Given that the 2003-2005 plague infested parts of Mali during the third quarter of 2004, the locust swarms could have affected substantially the planting and the growing season of the 2004 agricultural season, scheduled to be harvested in October of that year. Food supply on local markets before October 2004 came from harvest of the previous year and should not have been affected by the plague. Acknowledging this, we identify three potential channels through which locust invasion could have affected households: (i) a speculative price effect, (ii) a local crop supply/income shock effect, and (iii) a potential long term effect on agricultural production.

4.1 Speculative price effect

Between July and October 2004, the peak of the plague, households and markets were still relying on agricultural production from the previous season, harvested by the end of 2003. Therefore, there was no threat to food supply in this time window. However, there could have been a speculative price effect in anticipation of the imminent harvest failure in locust affected areas. The mere exposure to the plague could have led to severe inflation of local crop prices and harm households with limited resources, especially because the plague happened during the lean season.¹⁰ There is substantial evidence that suggest that this was actually the case. Several crisis monitoring reports on the plague document in fact a steep rise of crop prices in locust affected areas before the harvest of 2004 (FAO (2005a), FAO (2005b)). It is therefore possible, for instance,

¹⁰The lean season is a period of seasonal poverty in rural areas between planting and harvest periods when stocks of food are the lowest, there is no income and families often miss meals.

that children that were in utero during the third quarter of 2004 were affected by this speculative price effect even though markets and households were still relying on harvests not affected by the plague.¹¹

This speculative price effect will be a negative shock for households that are net buyers of local crops in that period, but a positive income shock for those that are net sellers. Net sellers during the lean season in Mali are typically a small share of relatively rich households that buy local crops after each harvest and sell them throughout the year on the markets. In absence of any information on the economic activity of household members, the effect that we estimate will be an average effect that might be attenuated by the positive income effect from net sellers depending on their relative size. This attenuation effect might also occur in the actual crop failure effect described next.

4.2 Local Crop Supply/Income Shock Effect

The harvest that was directly affected by the locust swarms was gathered between October and November 2004. Households and local markets had to rely on this potentially bad harvest until the next one, gathered in October 2005. We can therefore expect that areas affected by locust invasions have been treated during all this period by the actual local crop supply shock. This agricultural production shock could have negatively affected all households that are net buyers of local crops through the increase in market prices. It could have also harmed farming households that had their fields invaded by the swarms (a direct income shock).¹²

The absence of data on crop prices at local level prevents us from disentangling the price effect that comes from crop supply shock from the income shock effect in the period when house-

¹¹Lack of data availability on local crop prices in this period for Mali prevents us from controlling explicitly for prices in the analysis that follows.

¹²Locust swarms can also affect livestock farmers through a decrease in available pasture.

holds are relying on locust affected harvest. However, we are still able to test whether there is any speculative price effect during the few months when the locust invasion is happening and households are still relying on the previous harvest.

4.3 Potential Long Term Effect on Agricultural Production

The adverse effects of the plague should have disappeared after the harvest of November 2005, unless the crop failure in 2004 affected the quality of seeds used for the next harvest, or the income shock led to a depletion of productive assets (livestock, for instance). This would have led to a persistent effect, in the medium-run, on household food availability. We found no evidence suggesting that subsequent harvest suffered from locust swarm. First, there is no account of such effect from reports produced by agencies such as FAO. Moreover, we will show empirically in next sections that there are no differences in health status between children born in the locust affected areas and children born in non-affected areas, after the harvest of 2005.¹³

5 Empirical Strategy

We adopt a Difference-in-Differences approach to estimate the causal impact of locust invasions on child health. First, we define treatment and control groups at enumeration area level, by setting as treated, clusters within 30 kilometers of a locust swarm event. Then, we exploit all the available variation in childhood exposure to treatment across enumeration areas and birth cohorts.

¹³We cannot completely rule out the possibility that the asset depletion channel may have impacted substantially a certain share of households. However, since we do not find any evidence of a persistent effect in the data, we conclude that, if anything, the size of this share of household was marginal.

We estimate the following model:

$$y_{i(h,t,e)} = \gamma T_{i(t,e)} + \mu_e + \beta_t + \theta_{hh} X_h + \theta_1 X_{i(h,t,e)}^{(1)} + \theta_2 X_{i(t,e)}^{(2)} + \epsilon_{i(h,t,e)}, \quad (1)$$

where i denotes a child belonging to cohort t (year-month), born in household h who lives in enumeration area e .¹⁴ The dependent variable $y_{i(h,t,e)}$ measures height-for-age Z-score of child i . The treatment variable is $T_{i(t,e)}$, a dummy that takes a value of one if child i belongs to an enumeration area in the treatment group and has been exposed in utero to the adverse effects of the plague, i.e. being born between July 2004 and June 2006 in a locust affected area.

We control for μ_e and β_t that are enumeration area and birth cohort fixed effects respectively. $X_{i(h,t,e)}^{(1)}$ and $X_{i(t,e)}^{(2)}$ are observable characteristics at individual level (gender, birth order among siblings, age gap with direct older and younger siblings, etc.) and enumeration area level (Standardized Precipitation-Evapotranspiration Index (SPEI) drought index), respectively. Finally, X_h is a vector that includes household level controls, such as gender and age of household head, wealth index of household, education of the mother. Standard errors are clustered at the 0.5° grid cell level (see section 3.2).

In the baseline specification of the model in equation 1, we control only for enumeration area fixed effects to account for permanent unobserved characteristics of the place of residence and cohort fixed effects to account for cohort specific shocks, whereas the full version of the model includes controls for the relevant household and child characteristics.

Our coefficient of interest is γ , which measures the average difference in changes of height-for-age Z-scores of children born in locust infested areas and children born in non-infested areas,

¹⁴We omit from the notation, for neatness, the grid-cell g where enumeration area e lays over (see section 3.2). When estimating the model (1) with the two DHS waves, we replace the cluster fixed effects by grid cell fixed effects in order to compare geographical units consistent across waves. In that case, we add to (1) a dummy for treatment status at the cluster e level.

holding constant all the other relevant characteristics. The implicit assumption behind this identification strategy is that, after controlling for cohort and enumeration area fixed effects, household characteristics, and other relevant exogenous covariates, changes in height-for-age Z-scores would be similar across locust infested areas and non-infested areas in absence of the plague. Given that we control for cohort and enumeration area fixed effects, the coefficient γ does not represent the national impact of locust plague but the average effect with respect to local and cohort averages.

6 Empirical Results

6.1 Main Results

Table 3 displays the point estimates of γ in Equation 1. Column (1) shows the estimated coefficients of the baseline specification of our model, in which we control only for location fixed effects and cohort fixed effects. The variable of interest is a dummy equal to one for children born in locust affected areas between July 2004 (beginning of locust plague) and June 2006, i.e. the last cohort of children that relied on the 2004-2005 agricultural campaign harvest while in utero. Estimates are negative and statistically significant. They are robust and remain significant after progressively adding controls for child characteristics in column (2) and family characteristics in column (3). Our main specification in column (3) suggests that exposed children have, on average, a Z-score 0.33 points below the one of non-exposed children. This represents approximately a 25% decrease in the average Z-score for children in our sample and a 27.5% increase in the average stunting rate.¹⁵

¹⁵Stunting rate is defined as the share of children with height-for-age Z-score smaller than -2 standard deviations. Average stunting rate in our sample is 33%.

The estimated impact γ is also robust to the inclusion of region-specific time trends (Column (4)). Column (5) restricts the estimation sample to children measured only during the 2006 wave, hence we use older cohorts born before 2004 as non-treated cohorts to build the counterfactual trends. Column (6) does the opposite by restricting the estimation sample to children born after 2004. In this case, non-treated cohorts are younger cohorts born after June 2006. Results remain stable in both specifications.

Table 3: Impact of Locust Plague on Child Health

	(1)	(2)	(3)	(4)	(5)	(6)
	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score
In utero treatment	-0.391*** (0.099)	-0.354*** (0.100)	-0.331*** (0.101)	-0.323*** (0.098)	-0.384*** (0.114)	-0.308*** (0.101)
Observations	14,175	14,175	14,175	14,175	9,571	9,904
Average Height-age Z-score	-1.28	-1.28	-1.28	-1.28	-1.36	-1.16
R-squared	0.182	0.203	0.226	0.227	0.254	0.249
Cohort FE	YES	YES	YES	YES	YES	YES
Location FE	YES	YES	YES	YES	YES	YES
Region-specific time trends	NO	NO	NO	YES	NO	NO
Child characteristics	NO	YES	YES	YES	YES	YES
Family characteristics	NO	NO	YES	YES	YES	YES

Full set of controls includes mother's height, education, gender and age of household head, household wealth index, SPEI index, birth order, time gap between conception and the previous and following pregnancies. Robust standard errors in parentheses are clustered at enumeration area level. *** p<0.01, ** p<0.05, * p<0.1. Column (1) controls only for cohort and location fixed-effects. Column (2) and Column (3) include progressively child characteristics and family characteristics. Column (4) adds to the previous controls region-specific time trends. Column (5) uses data only from the 2006 wave of the DHS survey, while Column (6) uses as non-treated cohorts children born after June 2006. In these two specifications we control for cohort and location fixed-effects, as well as child and family characteristics.

6.2 Timing of the Estimated Effect, Channels and Placebo Test

The data we use allows us to test whether the estimated effect comes from the *speculative price effect* or the *crop failure effect*. To do so, we estimate the impact of being born in a locust affected area for different birth cohorts around the treatment window.

Figure 7 depicts the estimated impact of being born in locust infested areas by quarter of birth between years 2003 and 2008, together with the 95% confidence bands of each coefficient.¹⁶ The dashed line represents the quarter when the locust plague started in Mali. This figure shows that children born before the plague (third quarter of 2004), i.e. between the first quarter of 2003 and the second quarter of 2004 both included, have height-for-age Z-scores comparable to control cohorts. This shows that children already born when the plague hit did not suffer any effect perceptible in their height-for-age Z-scores. It also validates the hypothesis that the estimated impact that we documented in previous section is not capturing pre-existing trend differences between treated and non-treated areas.

Moreover, between the second quarter of year 2004 and the first quarter of 2006, there is a clear drop in our coefficient of interest, which becomes negative and statistically significant (estimates for quarter four year 2004 and quarter one and two year 2005 are significant at 90% confidence level). This corroborates our hypothesis that all the cohorts of children that have been exposed in utero to the plague suffered substantial health setbacks.

The estimated coefficient turns negative and significant for children born in July, August, or September 2004, i.e. the first three months of the locust invasion in Mali. According to the seasonal calendar reported in Figure 6, these children, during the onset of the plague, were still relying on the previous harvest that has not been affected by locust. Thus, this evidence

¹⁶The 2006 DHS survey data was collected between May and December so we restrict the analysis to children born before April 2006 to prevent survey timing biases from contaminating the estimated effect. The oldest cohorts with anthropometric measures from 2012-2013 survey were born in 2008.

validates the hypothesis that negative impact on their health status was driven by speculations on the current agricultural campaign, which led to a sharp increase in prices of local food products.¹⁷

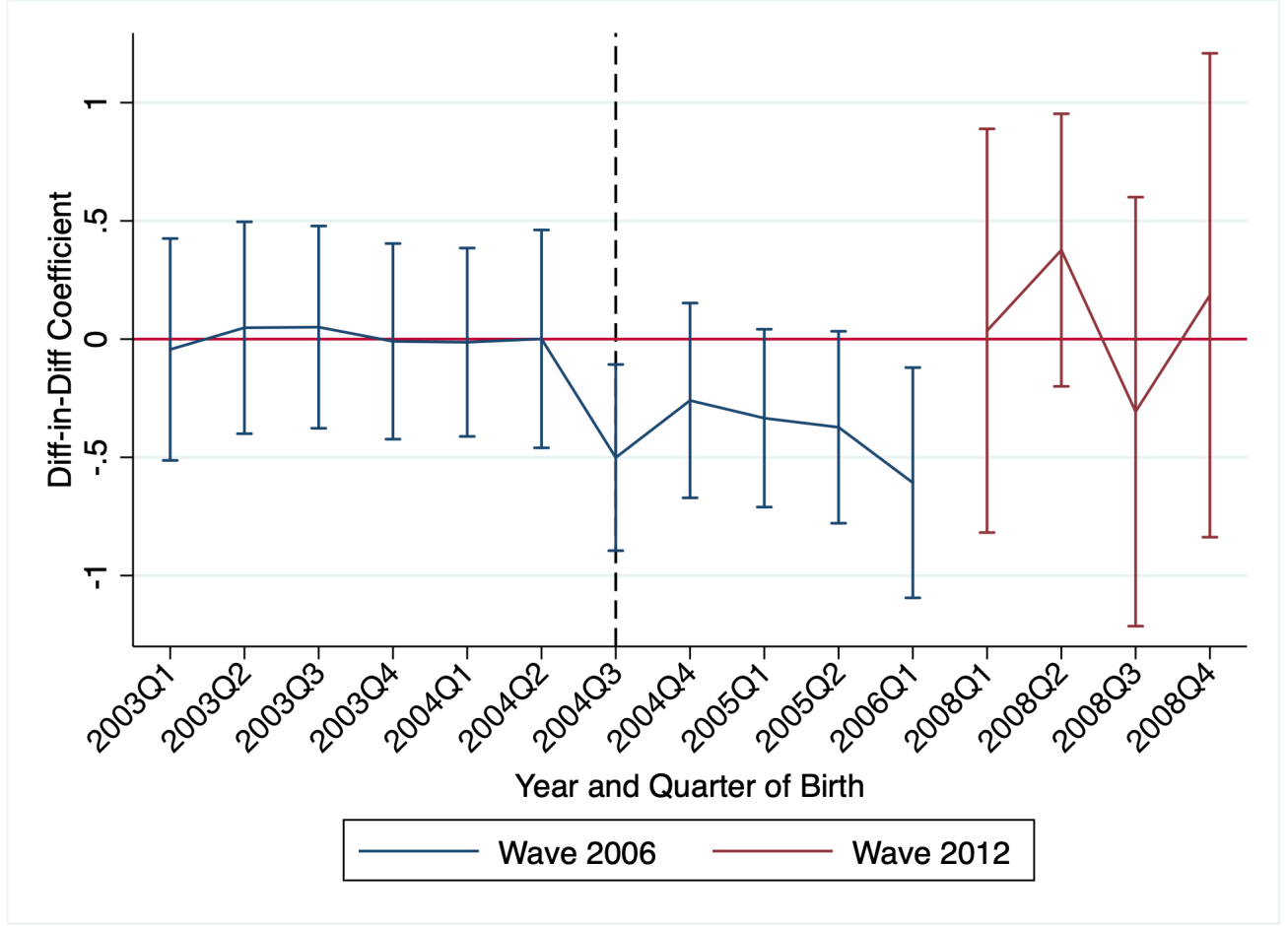
Figure 7 plots negative coefficients also for children born between September 2004 and March 2006. These groups were relying on harvest of the 2004-2005 season, i.e. the harvest that was directly damaged by the locust swarms. Therefore, on top of the speculative price effect, these children were also potentially subject to the supply/income shock due to the failed harvest while in utero. The negative and significant impact found for these cohorts supports this idea.

Finally, Figure 7 also depicts the estimated coefficients on younger cohorts, born after the plague ended, namely children born between January and December 2008. Those children were 4 to 5 years old at the time of the survey when they were measured so estimated coefficients are noisier and more volatile from quarter to quarter. There is however no clear trend and the estimated impact is oscillating around zero.¹⁸ Given that the health status of children born in the locust affected areas (after the plague ended) is comparable to the health status of children born in non-affected areas, we can infer that the 2003-2005 plague did not have any perceptible long-lasting effects. The harvest gathered during the 2005-2006 season seems not to have been impacted by the damages which took place during the previous season.

¹⁷Children born during the third quarter of 2004 are also exposed to the crop failure effect but only after birth and we found no effect of the plague after birth (see older cohorts of children in Figure 7).

¹⁸We show in Appendix a similar result in a placebo test where we consider older cohorts of children in the 2012 wave as not affected by the plague and younger cohorts of children as potentially affected by the plague.

Figure 7: Estimated Impact of 2004 Locust Invasion in Mali



Source: SWARMS data base from FAO Desert Locust Information Service and DHS data, Mali waves 2006 and 2012. This figure depicts the estimated coefficient of locust invasion on height-for-age Z-scores for each quarter-year cohort born in locust invaded areas between January 2003 and December 2008. Each coefficient is plotted together with its 95% confidence bands. The blue colored coefficients are obtained using height-for-age Z-scores computed during the 2006 DHS survey, while the red ones are obtained using height-for-age Z-scores computed during the wave held in 2012. The black dashed vertical line shows the quarter of the onset of the locust plague in Mali.

6.3 Heterogeneous Effects and Robustness Checks

While overall estimates point towards a substantial health setbacks for exposed children, it is not necessarily the case for all the sub-groups in our sample. Investigating whether the estimated

impact is driven by specific sub-groups of population can be useful for understanding the channels through which this effect is operating. Therefore, we run our main specification (the one that includes child and family characteristics in Column (3) of Table 3) on several sub-samples. Results are described in Table 4.

First of all, one important aspect around which the effects found could differ is gender. Usually, the literature on early childhood development finds a large negative bias against girls ([Dagnelie et al., 2018](#)). We find, instead, a negative impact of the plague on children of both genders. The estimates for these two sub-samples are documented in columns (1) and (2), which restricts the sample only to male and female children respectively. The negative impact of locust invasions on child health is stronger and statistically significant for the sub-sample of males, whereas for the female population it is only marginally significant (the p-value of the coefficient equals 0.1). We also estimate in Table A1 (appendix) a simple regression to test whether the magnitude of the impact is statistically different across gender. For that we run the main specification with an interaction term for the treatment variable and a female dummy variable including all the children in the sample. The result shows that the magnitude of the treatment effect is not statistically different across gender groups.

Another dimension across which results could differ is across place of residence: urban or rural. We explore this aspect in Columns (3) and (4) of Table 4, which displays results obtained from sub-samples including rural-located and urban-located households respectively. Results suggest that the negative effect is present in both sub-samples. The estimated coefficient is larger for children born in rural area but the difference is not statistically significant. This suggest that the adverse effect of the plague had a strong market effect and did not just affect the farmers living in rural areas.

It is well established in the literature that households build up risk coping mechanisms to insure against an agricultural shock such as the damage caused by a locust plague ([Townsend et](#)

al., 1994; Townsend, 1995). One obvious insurance mechanism is having assets, which households could use to cope with the shock. Exact data on the value of assets held at the household level is not available from the DHS data. However, DHS surveys classify households, based on their ownership of selected assets, in wealth quintiles.¹⁹ We define households as poor (rich) if they belong to the two bottom (top) quintiles. Those in the third quintile are classified as middle income households. The estimation for each of these groups (shown in Columns (5) to (7)) supports the idea that having assets may have helped households cope with the shock induced by the plague. In particular, the estimated impact on the poorest households is negative and more precisely estimated compared to richer groups. There is however no difference in the estimated magnitudes.

The last exercise of robustness concerns issues related to potential migration. One possible concern is that children in our sample were measured after the plague took place, and some of them may have migrated to their new place of residence after the plague which makes it impossible to attribute them to the right treatment group. Moreover, a subgroup of those that have migrated across treatment areas might have been positively or negatively selected, leading to potential biases in the estimates. For instance, richer households may move out of the treated areas after the plague leading to an upward bias in the estimated coefficient. We use information on number of years of residence in the locations where each household has been surveyed and we run regressions restricting the sample to those that lived at the same location for at least 2 years (Column 8) and those that have always lived there (Column 9). Results are robust in both cases suggesting that our estimates are not affected by potential migration.²⁰

¹⁹The classification is done with a principal component analysis whose inputs are household ownership of assets such as televisions and bicycles, together with the materials used for housing construction and the types of water access and sanitation facilities.

²⁰Further robustness checks that include a mother fixed effect specification, and changes in the size of the area considered for treatment are also discussed in appendix (Table A1 and Figure A1).

Table 4: Robustness: Impact of Locust Plague on Child Health

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Gender		Location		Wealth Index		Years of Residence		
	Male	Female	Rural	Urban	Poor	Middle	Rich	2+ years	Always
	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score	Height-age Z-score
In utero treatment	-0.410*** (0.107)	-0.244 (0.149)	-0.390*** (0.114)	-0.181 (0.129)	-0.265** (0.113)	-0.260 (0.183)	-0.237 (0.160)	-0.318*** (0.111)	-0.357*** (0.127)
Observations	7,195	6,980	10,232	3,943	5,734	2,956	5,485	9,670	5,464
R-squared	0.233	0.256	0.241	0.184	0.253	0.296	0.187	0.234	0.247
Cohort FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Location FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Child characteristics	YES	YES	YES	YES	YES	YES	YES	YES	YES
Family characteristics	YES	YES	YES	YES	YES	YES	YES	YES	YES

Dependent variable is HAZ. Full set of controls includes mother's height, education, gender and age of household head, household wealth index, SPEI index, birth order, time gap between conception and the previous and following pregnancies. Robust standard errors in parentheses are clustered at enumeration area level. *** p<0.01, ** p<0.05, * p<0.1. Column (1) reports the result of baseline specification of our model, restricting the sample to male. Column (2) does the same for female children. In Column (3) the subsample of interest includes only households located in rural areas, while Column (4) includes only households located in urban areas. Columns (5), (6) and (7) distinguish among children belonging to poor, middle and rich households. The specifications of Column (8) and Column (9) restricts the sample to households that report to be living in the location of the interview for at least 2 years or since ever, respectively.

7 Concluding remarks

In this paper we show that in utero exposure to desert locust plagues can lead to substantial health setbacks early in life. We estimate the causal impact of the 2004 plague that occurred in Mali on health status of children located in the Malian territories invaded by locust swarms. Our results suggests that there were both a strong speculative price effect of the locust invasion that kicked in during the plague itself, and a local crop supply shock that lasted at least until the next harvest. We also show that the locust invasion did not have any effect after birth.

We find that exposed children have, on average, a Z-score 0.39 points than non-exposed children. The estimated effects are stronger and/or more precisely estimated for children born in rural areas and, in general, belonging to poorer households. In contrast with the latest findings in the literature, we find no strong evidence for a gender imbalance of the effects of this shock in utero.

This study has relevant implications from a policy perspective. In particular, our results suggest that it is important to address expectations during pest invasions that affect agricultural production. It is crucial to put efforts in two main directions: (i) prevent price speculations and inflation; (ii) provide safety nets to the most vulnerable households in order to dampen the consequences of these shocks on young children.

With the alarming climate change prospects, one can expect more frequent extreme weather conditions in the breeding areas of desert locust and this could lead potentially to more plagues in the future. Preparing to limit the consequences of such locust invasions is thus necessary for policy makers that operate in the invasion areas of desert locust.

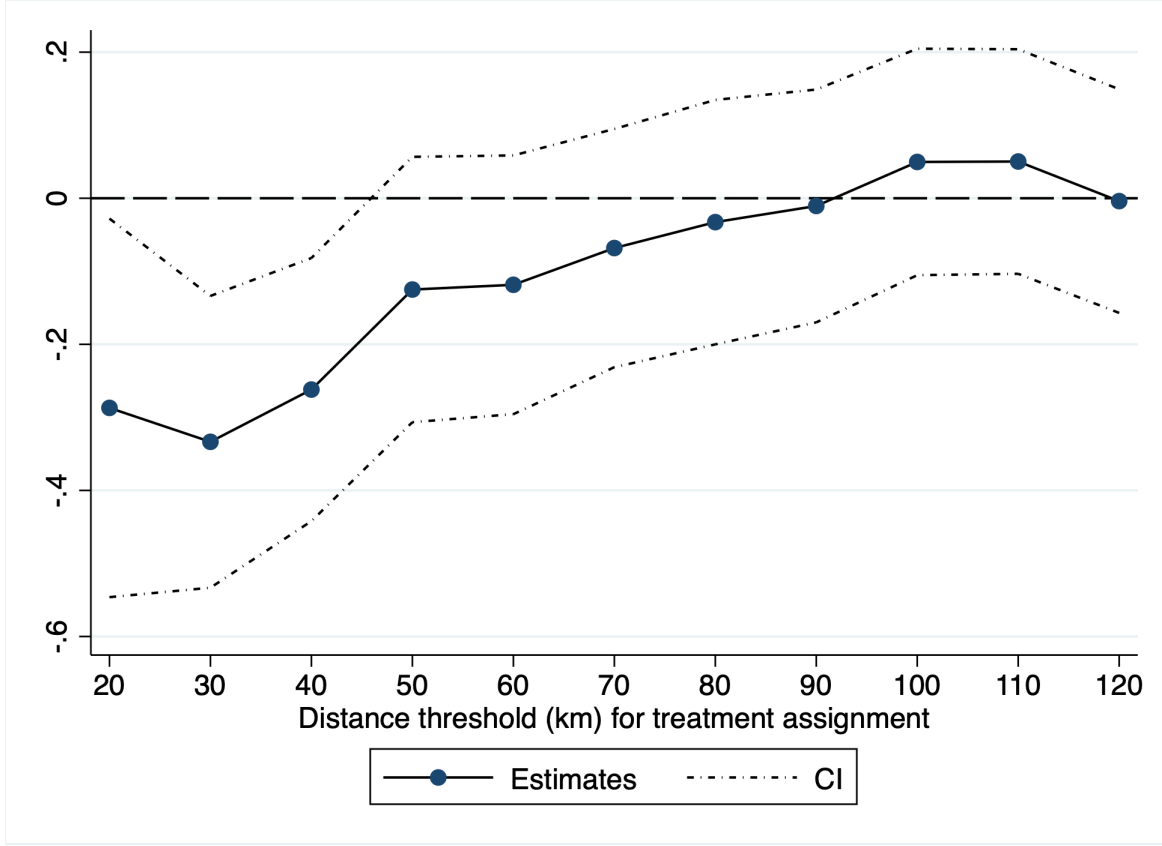
Appendix

A.1 Changing the Treatment Definition

In this Appendix we explore how our main results change, by changing the treatment definition. Specifically, we run several specification of our baseline model described in Equation 1 (Section 5), where in each iteration we change the definition of *treatment group*. In particular, in the first specification an area is defined as *locust affected* if it is located at most 20 km from at least one swarm event during the 2004 plague. In the subsequent specifications we add progressively 10 km to the threshold that defines what is a treatment area, up to 120 km.

Figure A1 plots the estimates of γ for each performed specification, together with their 95% confidence bands. It can be noticed that the adverse effect of locust invasions on child health is both negative and statistically significant for thresholds up to 40 km. After that, the effects approaches zero and it loses significance. This is consistent with the idea that locusts invasions are events that have adverse *local* effects.

Figure A1: Local Impact of Locust Plague on Child Health



Source: SWARMS data base from FAO Desert Locust Information Service and DHS data, Mali waves 2006 and 2012.

A.2 Additional Analysis

In this Appendix we perform additional robustness checks. In particular, we perform alternative specifications of the model described in Equation 1. Column (1) performs a placebo test using data from the 2012 DHS Wave. Treated children are those born in treated areas after 2011. We can see that there is no effect on these cohorts. In Column (2) we show that, weighting the data using DHS Sample Weights, the treatment effect is still negative and statistically significant. Column (3) uses an alternative definition of locust affected areas. In this case, areas are Malian *Communes*, i.e. third level administrative units, where at least one swarm event occurred during

the 2004 plague. The effects is negative and statistically significant, but lower than the one obtained in the baseline specification. This result is consistent with the evidence presented in Appendix A.1, according to which the severity of the effects of locust invasions decreases progressively if we consider as treated a wider area. In Column (3) we estimate a model to test whether the magnitude of the impact of locust invasions is statistically different across gender. To do so, we include an interaction term for the treatment variable and a female dummy variable including all the children in the sample. The result shows that the magnitude of the treatment effect is not statistically different across gender groups. In Column (4) we perform the corresponding exercise to test if the magnitude of the impact of the plague differs significantly across household location. We include an interaction term between the treatment variable and a dummy that equals one if the household is located in rural areas. The results show that the adverse effects of locust invasions are not statistically different between rural and urban households. The last specification, whose results are reported in Column (5), controls for mother fixed-effects. The effects remains negative and statistically significant.

A.3 Climate Data

In order to account for potential weather-related omitted variables in our analysis, we collect data from the Standardized Precipitation-Evapotranspiration Index (SPEI, see [Vicente-Serrano et al., 2010](#)). The SPEI is a multi scalar index that jointly maps rainfall, temperature and potential evaporation into a standardized index of drought. Importantly, it is measured in units of standard deviations from the long term average (1901 – 2015 in version 2.5), and has zero average by construction. It is available in a 0.5 x 0.5 grid, which is matched to the household coordinates available from the DHS surveys.

We want to control for exposure of individual pregnancies to food supply shocks due to weather conditions in our empirical specification. To do so we need to determine how weather

affects each mother’s nutritional intake during the 9 months in utero. We follow [Kudamatsu et al. \(2016\)](#) and focus on variations in SPEI index during the relevant growing seasons, as summarized by a simple index constructed as follows.

The relevant growing seasons of an individual birth depends on its timing relative to local harvest time. We weight the last 3 harvests before birth of cohort t (year-month) by the number of months that a pregnant woman will spend relying on each of them.

$$SPEI^{g,t} = \sum_{i=1}^3 \omega_i S_{a(t)-i}^{g,t},$$

where $\sum_i \omega_i = 1$, $S_{a(t)}^{g,t}$ is average SPEI index in cell g during the growing season of the year in which children of cohort t are born. For example, children born in January of a given year a (conceived in April of previous year), spend 3 months relying on harvest from year $a - 1$ (October to December) and 6 months relying on the harvest of year $a - 2$ (April till September) so the weights are 0/9, 3/9 and 6/9 for $\omega_0, \omega_1, \omega_2$, respectively. The results are robust to using SPEI for the last 3 years as separate variables. They also do not change when we consider SPEI for the entire year.

Table A1: Additional Analyses: Impact of Locust Plague on Child Health

	(1) Height-age Z-score	(2) Height-age Z-score	(3) Height-age Z-score	(4) Height-age Z-score	(5) Height-age Z-score	(6) Height-age Z-score
Placebo treatment	0.150 (0.195)					
In utero treatment		-0.280** (0.112)		-0.391*** (0.095)	-0.396*** (0.123)	-0.162** (0.070)
In utero treatment (administrative area)			-0.191* (0.106)			
In utero treatment \times female child				0.121 (0.117)		
In utero treatment \times rural household					0.088 (0.115)	
Observations	4,182	14,175	14,175	14,175	14,175	14,175
R-squared	0.346	0.238	0.225	0.226	0.226	
Cohort FE	YES	YES	YES	YES	YES	YES
Location FE	YES	YES	YES	YES	YES	
Child characteristics	YES	YES	YES	YES	YES	YES
Family characteristics	YES	YES	YES	YES	YES	
Number of mothers						10,374
Mother FE						YES

Robust standard errors in parentheses are clustered at enumeration area level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Column (1) uses data from the 2012 wave and uses as treatment group children born in locust affected areas, after 2011. Column (2) weights the data with the DHS Sample Weights. In Column (3) treated areas are Malian Communes where at least one swarm related event occurred in 2004. Columns (4) and (5) include an interaction term between the treatment variable and the female and rural dummy, respectively. Column (6) controls for mother fixed-effects.

References

- Akbulut-Yuksel, Mevlude**, “War during childhood: The long run effects of warfare on health,” *Journal of health economics*, 2017, *53*, 117–130.
- Akresh, Richard, Leonardo Lucchetti, and Harsha Thirumurthy**, “Wars and Child Health: Evidence from the Eritrean–Ethiopian Conflict,” *Journal of Development Economics*, 2012, *99* (2), 330–340.
- , **Philip Verwimp, and Tom Bundervoet**, “Civil war, crop failure, and child stunting in Rwanda,” *Economic Development and Cultural Change*, 2011, *59* (4), 777–810.
- , **Sonia Bhalotra, Marinella Leone, and Una Okonkwo Osili**, “War and Stature: Growing Up During the Nigerian Civil War,” *The American Economic Review (Papers and Proceedings)*, 2012, *102* (3), 273–277.
- Alderman, Harold, John Hoddinott, and Bill Kinsey**, “Long term consequences of early childhood malnutrition,” *Oxford economic papers*, 2006, *58* (3), 450–474.
- Almond, Douglas and Janet Currie**, “Killing Me Softly: The Fetal Origins Hypothesis,” *Journal of Economic Perspectives*, September 2011, *25* (3), 153–72.
- , **Lena Edlund, Hongbin Li, and Junsen Zhang**, “Long-term effects of the 1959-1961 China famine: Mainland China and Hong Kong,” Technical Report, National Bureau of Economic Research 2007.
- Baker, Richard B, John Blanchette, and Katherine Eriksson**, “Long-run Impacts of Agricultural Shocks on Educational Attainment: Evidence from the Boll Weevil,” Technical Report, National Bureau of Economic Research 2018.

- Banerjee, Abhijit, Esther Duflo, Gilles Postel-Vinay, and Tim Watts**, “Long Run Health Impacts of Income Shocks: Wine and Phylloxera in 19th Century France,” *The Review of Economics and Statistics*, 2010, *92* (4), 714–728.
- Behrman, Jere R and Mark R Rosenzweig**, “Returns to Birthweight,” *Review of Economics and Statistics*, 2004, *86* (2), 586–601.
- Black, Sandra E, Paul J Devereux, and Kjell G Salvanes**, “From the Cradle to the Labor Market? The Effect of Birth Weight on Adult Outcomes,” *The Quarterly Journal of Economics*, 2007, *122* (1), 409–439.
- Brader, L, H Djibo, FG Faye, S Ghaout, M Lazar, PN Luzietoso, and MA Ould Babah**, “Towards a more effective response to desert locusts and their impacts on food security, livelihoods and poverty,” *Multilateral evaluation of the 2003–05 Desert locust campaign. Food and Agriculture Organisation, Rome*, 2006.
- Bundervoet, Tom, Philip Verwimp, and Richard Akresh**, “Health and Civil War in Rural Burundi,” *Journal of Human Resources*, 2009, *44* (2), 536–563.
- Ceccato, Pietro, Keith Cressman, Alessandra Giannini, and Sylwia Trzaska**, “The desert locust upsurge in West Africa (2003–2005): Information on the desert locust early warning system and the prospects for seasonal climate forecasting,” *International Journal of Pest Management*, 2007, *53* (1), 7–13.
- Cressman, K**, “SWARMS: a geographic information system for desert locust forecasting,” in “New Strategies in locust control,” Springer, 1997, pp. 27–35.
- Cressman, Keith and Robert Stefanski**, “Weather and Desert Locusts,” Technical Report, World Meteorological Organization and Food and Agriculture Organization of the United Nations 2016.

Dagnelie, Olivier, Giacomo De Luca, and Jean-François Maystadt, “Violence, Selection and Infant Mortality in Congo,” *Journal of Health Economics*, 2018.

FAO, “Locust crisis to hit northwest Africa again - situation deteriorating in the Sahel (last visit 05.06.2018),” September 2004.

—, “West African food crisis looming (last visit 05.06.2018),” June 2005.

—, “Worsening food situation in parts of the Sahel (last visit 05.06.2018),” May 2005.

FEWS-NET, “Senegal: monthly food security update,” *FEWS NET monthly report*, 2005.

Herok, Claudia A, Stephan Krall et al., *Economics of Desert locust control.*, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, 1995.

Kudamatsu, Masayuki, “Has Democratization Reduced Infant Mortality in Sub-Saharan Africa? Evidence from Micro Data,” *Journal of the European Economic Association*, 2012, 10 (6), 1294–1317.

—, **Torsten Persson, and David Strömberg**, “Weather and Infant Mortality in Africa,” Technical Report, CEPR Discussion Papers 9222 2012.

—, —, **and** —, “Weather and Infant Mortality in Africa,” 2016.

Lavy, Victor, Analia Schlosser, and Adi Shany, “Out of Africa: Human Capital Consequences of In Utero Conditions,” Working Paper 21894, National Bureau of Economic Research January 2016.

Maccini, Sharon and Dean Yang, “Under the Weather: Health, Schooling, and Economic Consequences of Early Life Rainfall,” *American Economic Review*, 2009, 99 (3), 1006–26.

Maluccio, John A, John Hoddinott, Jere R Behrman, Reynaldo Martorell, Agnes R Quisumbing, and Aryeh D Stein, “The Impact of Improving Nutrition During Early

- Childhood on Education among Guatemalan Adults,” *The Economic Journal*, 2009, 119 (537), 734–763.
- Stein, Zena, Mervyn Susser, Gerhart Saenger, and Francis Marolla**, *Famine and Human Development: The Dutch Hunger Winter of 1944-1945.*, Oxford University Press, 1975.
- Symmons, PM, K Cressman, and HM Dobson**, “Desert locust guidelines,” 2001.
- Tollefsen, Andreas Forø, Håvard Strand, and Halvard Buhaug**, “PRIO-GRID: A Unified Spatial Sata Structure,” *Journal of Peace Research*, 2012, 49 (2), 363–374.
- Townsend, Robert M**, “Consumption insurance: An evaluation of risk-bearing systems in low-income economies,” *Journal of Economic perspectives*, 1995, 9 (3), 83–102.
- **et al.**, “Risk and insurance in village India,” *ECONOMETRICA-EVANSTON ILL-*, 1994, 62, 539–539.
- Valente, Christine**, “Civil Conflict, Gender-specific Fetal Loss, and Selection: A new Test of the Trivers–Willard hypothesis,” *Journal of Health Economics*, 2015, 39, 31–50.
- Vicente-Serrano, Sergio M, Santiago Beguería, and Juan I López-Moreno**, “A multi-scalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index,” *Journal of Climate*, 2010, 23 (7), 1696–1718.
- Vreyer, Philippe De, Nathalie Guilbert, and Sandrine Mesple-Somps**, “Impact of natural disasters on education outcomes: evidence from the 1987–89 locust plague in Mali,” *Journal of African Economies*, 2014, 24 (1), 57–100.